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Architectural Intelligence (ArcAI) Evolution and Progress on Sustainable Smartscapes Planning for the Cities of Tomorrow

Salmiah Aziz[1*], Siti Maryam Sharun[2], Khairul Rijal Wagiman[3], Chumporn Moorapun[4]
**Corresponding Author*

[1] Architectural Technology & Management Group, Faculty of Architecture and Ekistics, Universiti Malaysia Kelantan
[2] Faculty of Innovative Design & Technology, Universiti Sultan Zainal Abidin
[3] Renewable Energy Technology Focus Group, Universiti Tun Hussein Onn Malaysia
[4] Department of Interior Architecture, King Mongkut's Institute of Technology Ladkrabang

salmiah.a@umk.edu.my, sitimaryam@unisza.edu.my, khairulrw@uthm.edu.my, moorapun@yahoo.com
Tel: +601128804210

Abstract
Rapid urbanization and environmental concerns underscore the need for sustainable design in urban areas. This study delves into sustainable smart scapes, integrating eco-friendly practices and smart technologies to meet urban demands. It examines green infrastructure, renewable energy, and smart parameters' integration, assessing their effectiveness through literature review and case studies. Exploring technologies like Internet of Things (IoT), artificial intelligence (AI), and data analytics, the research adopts qualitative methods - case studies, structured interviews, and literature review – for a nuance understanding of. It aims to inform future sustainable architecture and urban planning, emphasizing smartscapes' role in resource optimization, economic growth, and community inclusivity, contributing to interdisciplinary knowledge advancement.

Keywords: Architectural Intelligence (ArchAI); Bioncentric architecture; Sustainable Smartscapes, Urban environment

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1.0 Introduction

Architectural Intelligence (ArcAI) is the integration of artificial intelligence (AI) and advanced computer technologies into architectural design, planning, and management processes to build long-term smartscapes. The concept involves utilizing AI algorithms, machine learning, and data analytics to improve the efficiency, functionality, and environmental performance of buildings and urban settings. ArcAI seeks to help architects, urban planners, and stakeholders make better decisions by giving insights, predictions, and suggestions for sustainable design solutions. It combines several aspects of sustainable design, such as energy efficiency, resource management, climate responsiveness, and user comfort, to produce smarter, more resilient, and ecologically conscious constructed environments. Cities that use ArcAI can improve their sustainability, resilience, and livability, ultimately contributing to building smarter, more sustainable cities in the future. Sustainable urban development is vital for solving today's environmental, social, and economic concerns in cities. As global urbanization accelerates, cities face critical concerns such as pollution, resource depletion, overpopulation, and undequal access to resources and opportunities. Sustainable urban development addresses these issues by supporting ecologically sustainable, socially inclusive, and economically viable approaches to urban expansion and management.

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In this context, new architectural solutions play a critical role in making the built environment more sustainable and resilient. Architectural intelligence (ArcAI) presents a significant opportunity to incorporate advanced technologies and data-driven approaches into architectural design, planning, and management processes. Using ArcAI, architects, urban planners, and policy makers can achieve several important objectives:

a) Environmental Sustainability: ArchAI allows for the optimization of building and urban designs to reduce energy consumption, carbon emissions, and improve resource efficiency. It promotes the use of renewable energy sources, green building materials, and efficient infrastructure systems to create ecologically sustainable built environments.
b) Resilience and Adaptation: ArcAI enables the prediction and mitigation of environmental risks and hazards such as extreme weather and natural disasters. ArcAI can assist detect weaknesses in urban systems and inform methods for increasing resilience and adaptive capacity by evaluating data and simulating scenarios.
c) Social Inclusivity: ArchAI supports the creation of inclusive and equitable urban spaces by considering the diverse needs and preferences of communities. It can help optimize the accessibility, affordability, and usability of built environments, ensuring that all residents have equal access to essential services, amenities, and opportunities.
d) Economic Viability: ArcAI-driven design and planning strategies can enhance the economic competitiveness and sustainability of cities by promoting innovation, efficiency, and productivity. By optimizing land use, infrastructure investments, and resource allocation, ArcAI contributes to the long-term economic prosperity of urban areas.

2.0 Literature Review

2.1 Evolution of Sustainable Urban Design Principles

Sustainable urban design ideas have evolved throughout time, from early environmental awareness to more comprehensive approaches today. Initially centered on resource conservation and pollution reduction, it has since extended to include larger objectives such as social equity, resilience, and climate adaptation. Mixed land use, compact development, and green infrastructure have all become popular concepts over time. This progression reflects an increasing understanding of the connection of human activities and the environment, as well as the necessity for comprehensive solutions to urban concerns. Today's sustainable urban design concepts stress the creation of habitable, equitable, and resilient communities that balance environmental, social, and economic factors.

Dr. Emily Greenfield's quote into the core principles of sustainable urban planning, emphasizing social equity, environmental conservation, efficient transportation, inclusive communities, economic viability, community engagement, and long-term vision. She highlights the importance of smart land use and mixed-use development to minimize urban sprawl and encourage walkability. Additionally, she highlights the significance of environmental conservation, renewable energy sources, and green infrastructure in mitigating the environmental impact of urbanization. Furthermore, efficient public transportation, affordable housing initiatives, and inclusive infrastructure play crucial roles in fostering social equity and creating vibrant, resilient communities. Moreover, she highlighted the economic viability of sustainable urban planning, promoting innovation, supporting local businesses, and planning for future challenges like climate change. Community engagement and long-term adaptability are essential principles to ensure that urban plans align with residents' needs and anticipate future changes. Overall, she concluded that the application of sustainable urban planning for a town planning, could guide cities toward a more sustainable and resilient future.

2.2 Sustainable Smartscapes: Key Principles Sustainable

Sustainable smartscapes are developed on a set of guiding principles that help urban planners, architects, and policymakers create environmentally conscious and technologically advanced urban environments. These principles include a wide range of areas, including the utilization of technology, environmental issues, and community engagement, all with the goal of creating resilient, livable, and inclusive communities for current and future generations. As quoted by Narmeen Zakaria Bawany (2015), the concept of smart cities aims to enhance citizens' quality of life by integrating information services across various domains such as health, education, transportation, power grid, etc. The research addresses ICT challenges in adapting to smart cities, emphasizing effective data management and network resource provisioning. The proposed architecture outlines a hierarchical data storage model, enabling seamless communication and service delivery by different stakeholders. This approach facilitates step-by-step implementation towards smart cities, ensuring timely integration of services as they develop, despite the significant challenges and requirements associated with such advancements in urban infrastructure and technology.

Figure 1 illustrates the primary layers of smart city. At its core lies the ICT infrastructure, serving as essential upon which all other elements depend. This infrastructure encompasses high-speed wired and wireless network connections, advanced data centers, as well as the integration of smart devices, sensors, and actuators throughout physical spaces. Figure 2 shows a comprehensive perspective on the suggested architectural design for central data management system of a smartcity and cloud service (N. Zakaria & N.J., 2015). The smart city concept is crucial for urban development and guides architectural design. It emphasizes technical feasibility and integrates energy efficiency and environmental protection. Smart technologies and high-tech equipment enhance urban functions and comfort. Combining smart city concept with moden architecture is vital, providing convenince and comfort for daily life. Designers must prioritize smart city principles for a better living environment (K. Madhee, 2024).

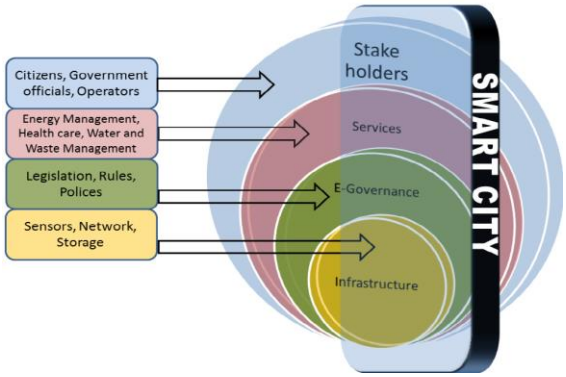

Figure 1: Smart city layers
(Source: N.Zakaria & N.J, 2015)

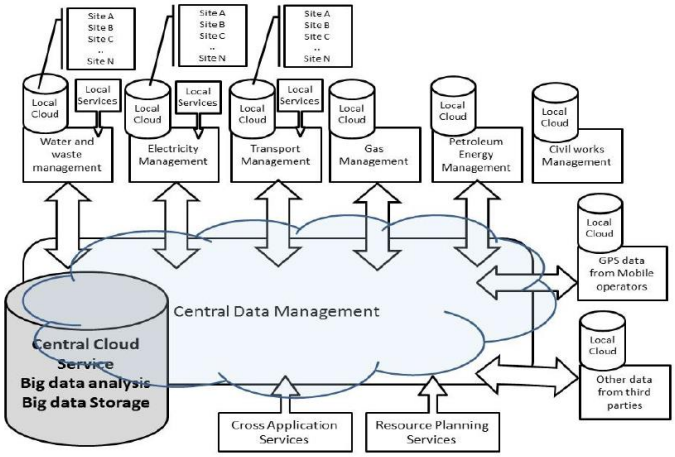

Figure 2: Holistic view of proposed
(Source: N.Zakaria & N.J, 2015)

Digital innovation is a significant force for urban transformation. Yet, cities are complex systems where innovation depends on various factors. The characteristics that drive innovation innovation in other areas don't always align well with urban ecosystem, leading to slower progress and frustration with the smart city concept (R. Jose & H. Rodrigues, 2024). One fundamental principle in sustainable smartscapes is the integration of advanced technology to enhance urban efficiency and functionality. This involves the incorporation of smart infrastructure, IoT devices, and data analytics platforms to optimize resource management, improve service delivery, and enhance the overall quality of life for residents. By leveraging technology, cities can reduce energy consumption, minimize waste generation, and enhance mobility through intelligent transportation systems.

In their 2024 study, Hossein Omary et al. identified seven primary challenges related to the adoption of Integrated Energy Systems in Cities (IESCs). These challenges include energy consumption, environmental concerns, data analysis, privacy and security issues, interoperability, ethical considerations, scalability, adaptability, and integration of IoT systems into urban development plans. The study also proposed recommendations to address these challenges and promote effective integration within policies to advance towards net-zero futures (Figure 3).

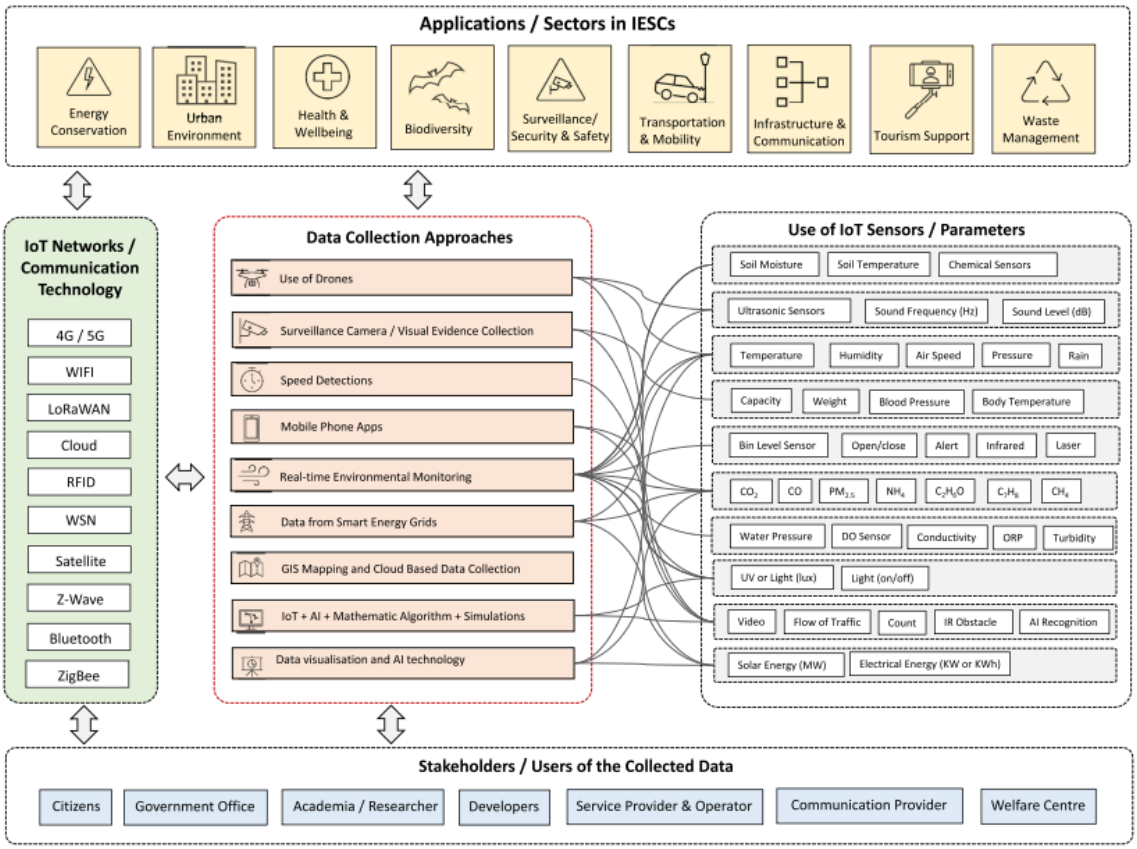

Figure 3: IoT-based data collection approaches in various application sectors of smart cities
(Source: Hossein Omary et al., 2024)

Governance aims for effective, efficient, and communicative local government, enhancing bureaucratic performance via integrated innovation and technology. Utilizing SWOT analysis guides strategic Smart City development. A robust network infrastructure, including Data Centre and NOC, ensures connectivity and interoperability. Smart City Supporting Application and Software Requirements enable synergetic e-Government services (M. Fadli & I. Sumitra, 2019). Using information and technology in city governance improves bureaucratic efficiency, a priority for both central and local governments in smart city transformation. Neglecting this renders smart city campaigns irrelevant. Standard application system requirements include reliability, interoperability, scalability, user-friendly, and integrability for all smart e-government applications (Figure 4).

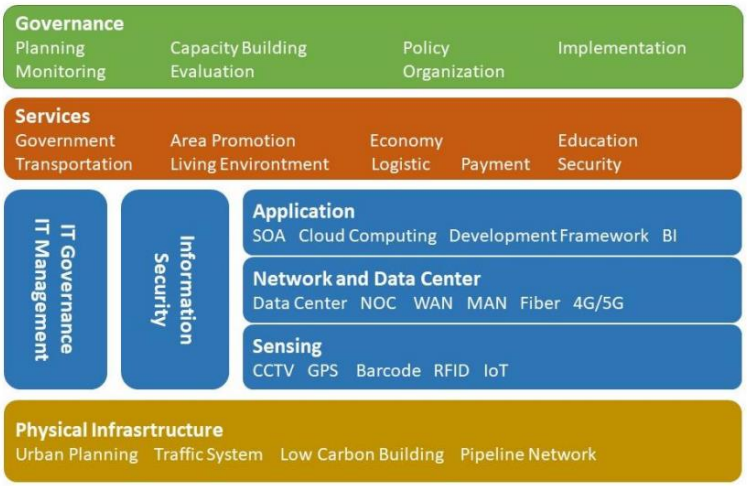

Figure 4: Smart e-government Application Architecture Framework
(Source: M.Fadli & I. Sumitra, 2019)

Environmental concerns are critical in developing sustainable smartscapes, with a focus on protecting natural ecosystems, lowering carbon emissions, and minimizing the effects of climate change. This principle highlights the value of green infrastructure, such as parks, green roofs, and permeable pavements, in promoting biodiversity, reducing urban heat islands, and managing stormwater runoff. Furthermore, sustainable building practices, such as passive design principles and energy-efficient technologies, are essential for lowering buildings' environmental footprints and supporting resource conservation.

Community engagement is another key principle guiding the development of sustainable smartscapes, emphasizing the active involvement of residents, businesses, and other stakeholders in the urban planning process. This principle seeks to empower communities to participate in decision-making, advocate for their needs and preferences, and co-create solutions that reflect local priorities and values. Through participatory planning approaches, cities can foster a sense of ownership, social cohesion, and inclusivity, ensuring that urban development projects align with the aspirations and aspirations of the people serve.

In summary, the key principles of sustainable smartscapes underscore the importance of integrating technology, environmental considerations, and community engagement in urban planning and development. By adhering to these principles, cities can create vibrant, resilient, and equitable urban environments that enhance the well-being of residents while preserving natural resources for future generations.

2.3 Conceptual Framework of Architectural Intelligence (ArcAI) and Its application in Urban Planning

Architectural intelligence's conceptual framework optimizes urban planning processes by integrating advanced technologies and data-driven methodologies. It includes the use of artificial intelligence (AI), machine learning, and big data analytics to study complex urban processes and make informed decisions. AI provides predictive modelling, scenario planning, and simulation to anticipate urban difficulties and create solutions in advance. Using real-time data and prediction algorithms, planners can optimize land use, transportation networks, and infrastructure development for sustainability and resilience. Finally, AI transforms urban planning by giving insights, projections, and suggestions to make cities smarter, more efficient, and resilient for future generations.

Architectural Intelligence (ArcAI) refers to the incorporation of artificial intelligence (AI) technologies into urban design processes, shaping how cities are designed, created, and operated. At its core, ArcAI employs AI algorithms and computational approaches to evaluate massive volumes of data, produce design options, and optimize urban areas for sustainability, usefulness, and aesthetics.

ArcAI plays an important role in improving the efficiency of and efficacy of urban design processes. Designers can use AI-drive algorithms to simulate and analyze different design scenarios, anticipate the performance of proposed interventions, and identify optimal solutions that balance several objectives including energy efficiency, mobility, and social equality. This data-driven method allows designers to make informed decisions and quickly iterate on ideas, resulting in more robust and responsive urban landscapes.

Furthermore, ArcAI facilitates the development of sustainable and habitable cities by providing innovative design solutions to complicated urban challenges. For example, AI-powered tools may optimize building orientation for solar exposure, establish efficient transportation networks, and improve green space allocation to increase biodiversity and reduce urban heat islands. Urban designers may use AI to develop cities that are not only ecologically sustainable, but also socially inclusive, economically vibrant, and culturally

rich, resulting in a high quality of life for both residents and visitors.

2.3.1 Satellite and Urban Design

Satellite alerts enhance smart urban design, infrastructure, and buildings in smart cities by providing real-time data for proactive decision-making and resource management. They optimize spatial layouts, mitigate environmental impacts, and improve livability. Integrated with ArcAI, they enable predictive maintenance, energy optimization, and network enhancement, ensuring efficient operations and resilience. Together, they empower informed decision-making, efficient resource management, and sustainable urban development, enhancing residents' quality of life.

2.4 Case Study (Precedent Studies)

This component explores real-world examples of smart city initiatives from around the globe. It examines case studies of cities that have implemented innovative technologies and strategies to enhance sustainability, efficiency, and livability. By analyzing successful projects and identifying lessons learned, the review provides insights into the practical application of smart city concepts and their potential for imforming future urban development strategies.

The smart and sustainable urban design case studies encompassed Copenhagen, Denmark; Curitiba, Brazil; Singapore; Malmo, Sweden; and the Garden City by Ebenezer Howard.

Howard's plan encompassed several key elements:

a) Acquisition of a substantial tract of agricultural land within a defined perimeter
b) Design of a condensed township encircled by an extensive rural buffer zone
c) Integration of residential, industrial, and agricultural sectors within the township
d) Regulation of town expansion to safeguard the integrity of the rural buffer
e) Utilization of organic appreciation in land worth for the overall benefit of the township

Principles of Garden Cities:

a) Collective land ownership ensures communal benefit from rising land values, not just individual gain.
b) Comprehensive planning yields positive economic and social outcomes on a large scale.
c) Establishment of compact communities fostering a harmonious blend of agricultural and industrial activities.
d) Promotion of urban decentralization for enhanced livability and sustainability.

3.0 Methodology

The research methodology used in investigating sustainable smartscapes and ArcAI includes qualitative research methods designed to investigate the complexity of these subjects. The researchers used case studies, structured interview questions, and a literature study (secondary data mining) to get a thorough understanding of sustainable urban design and advanced architectural technologies.

The incorporation of case studies (through observation and data gathering) enabled the investigation of real-world examples and practical applications of sustainable smartscapes and ArcAI in urban contexts. This method allowed the researchers to examine specific projects, initiatives, and innovations, gaining vital contextual knowledge and demonstrating best practices and obstacles. Structured interview questions were used to interact with six architectural and urban planning experts, practitioners, and stakeholders in the fields of sustainable urban development and architecture intelligence (ArcAI). The researchers' goal in these interviews was to obtain varied viewpoints, experiences, and ideas, enriching the qualitative data collected and contributing to a greater knowledge of the research issues.

In addition, a comprehensive literature analysis was carried out to support primary data collection efforts. By combining existing information, theories, and empirical data from academic and professional sources, the researchers placed their findings into the larger discourse on sustainable architecture and urban planning. Overall, the combination of case studies, organized interviews and a literature analysis enabled a thorough and nuanced examination of sustainable smartscapes and ArcAI. The researchers used different study approaches to unearth insights that could inform future improvements in sustainable urban design, technological innovation, and urban planning practices.

The researcher gathered data on smart cities and Architectural Intelligence (ArcAI) in Malaysia and Singapore to explore the practical challenges of implementing smart systems, with a particular emphasis on the Malaysian context within the Association of Southeast Asian Nations (ASEAN) region.

4.0 Data Collection

The researchers explored sustainable urban design and advanced architectural technologies, focusing on smart technology and AI. The researchers gathered data through two case studies on urban planning and smart city frameworks in Kuala Lumpur and Singapore (Figure 5, 6, 7 & 8). Additionally, the researchers conducted structured interviews with six experts, including two urban planning office principals and four architectural and academia experts. Furthermore, the researchers conducted a literature study through secondary

data mining (Figure 5, 6, 7 & 8). This comprehensive approach facilitated a deep understanding of the topic by combining real-world case analyses, expert perspectives, and existing literature.

From the literature review and data mining conducted through observations for the case study, the researchers identified seven key elements to consider in developing smart urban planning: smart economy, smart living, smart environment, smart people, smart government, smart mobility, and smart digital infrastructure. These seven criteria of smart cities, along with AI regulations in both countries, will be further analyzed and integrated with data from expert interviews to better understand the scope of urban planning in Malaysia and Singapore.

Figure 5: Kuala Lumpur Smart City Framework
(Source: Dewan Bandaraya Kuala Lumpur, 2023)

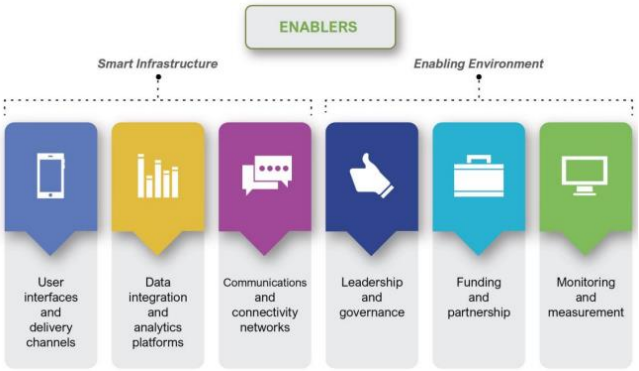

Figure 6: Kuala Lumpur Smart City Framework (Enablers)
(Source: Dewan Bandaraya Kuala Lumpur, 2023)

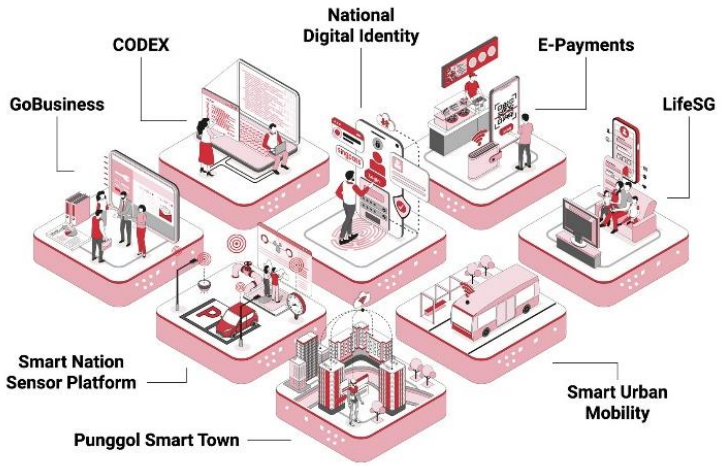

Figure 7: Singapore Smart Nation
(Source: Smart Nation Singapore, 2023)

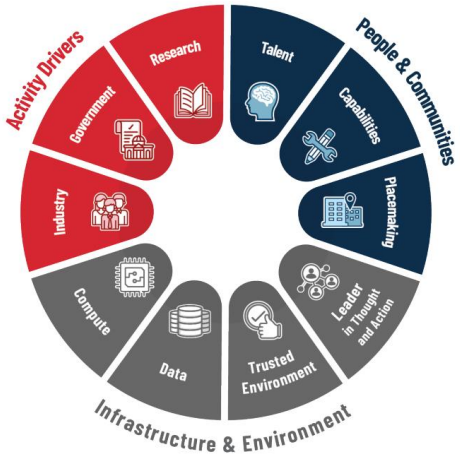

Figure 8: Singapore National AI Strategy (NAIS 2.0), 10 Enablers
(Source: Ministry of Communications and Information, Government of the Republic of Singapore, 2023)

5.0 Findings & Discussions

The Kuala Lumpur Smart City Framework, compared to Singapore's Smart Nation initiative, highlights that Malaysia is still in process of developing its smart systems and AI. In contrast, Singapore has already established, implemented, and regulated AI systems throughout the country. The research explores seven aspects regarding the evolution of sustainable smartscapes through ArcAI for future cities. These include smart economy (S1), smart living (S2), smart environment (S3), smart people (S4), smart government (S5), smart mobility

(S6), and smart digital infrastructure (S7). Examining these 7 codes in urban planning is crucial for practicing smartscapes and ArcAI in sustainable urban planning and advanced architectural design for future cities (Table 1).

Table 1. Six aspects of sustainable smartscape

Aspects	Descriptions	Code
Smart Economy	**Stakeholders find ArcAI to be a valuable resource management tool.** Architects and designers see its potential for innovation, while governments and investors appreciate its role in sustainable development and decision-making. **Successful adoption depends on technology readiness, government support, data privacy, and public-private partnerships.** Education and public perception also play crucial roles.	S1
Smart Living	ArcAI can improve cities by enhancing air quality, reducing noise, and increasing access to amenities. **It can help create self-regulating buildings, streamline traffic, and improve waste management**. **Integrating ArcAI in urban planning boosts efficiency, accuracy, and collaboration**. Challenges include skill requirements, initial costs, and data privacy concerns.	S2
Smart Environment	Challenges in urban sustainability include managing expansion, providing affordable housing, balancing development with environmental concerns, addressing climate change, preserving heritage, and managing population growth. Malaysian cities face rapid urbanization and resource strain. Collaboration across government agencies is essential. **ArcAI can enhance building resilience to climate change, optimize layouts, and improve collaboration among planners and architects.**	S3
Smart People	Community residents see ArcAI as a solution to issues like housing affordability and transportation. Adoption is influenced by education, development roles, consultancy, and public perception.	S4
Smart Government	Urban sustainability challenges include managing expansion, providing housing, balancing development and environmental concerns, addressing climate change, preserving heritage, and managing population growth. Rapid urbanization and resource strain are issues in Malaysian cities. Effective collaboration across government agencies is crucial. **Governments and investors recognize ArcAI's value for sustainable development. Adoption depends on policies, incentives, data privacy regulations, and partnerships.**	S5
Smart Mobility	ArcAI can enhance cities by improving air quality, noise levels, and amenities access. It can help streamline traffic and improve waste management**. Community residents see ArcAI as a solution to housing and transportation challenges.**	S6
Smart Digital Infrastructure	Integrating ArcAI into urban planning enhances efficiency, accuracy, and collaboration. It optimizes layouts, improves resource management, and transforms public services**. AI applications like GIS and BIM offer tools for spatial analytics and urban prototyping, improving sustainable design practices.** Ethical and privacy considerations need to be addressed.	S7

(Source: Author, 2024)

In Malaysia, urban sustainability faces challenges such as managing expansion, providing housing, balancing development with environmental concerns, addressing climate change, preserving heritage, and managing population growth. Rapid urbanization and resource strain are significant issues. Effective collaboration across government agencies is essential. While governments and investors see ArcAI as valuable for sustainable development, successful adoption depends on supportive policies, incentives, data privacy regulations, and public-private partnerships.

The Kuala Lumpur Smart City Framework leverages smart system across various sectors: enhancing resource management and innovation (Smart Economy), improving air quality and waste management (Smart Living), optimizing urban sustainability and climate resilience (Smart Environment), addressing housing and transportation (Smart People), managing urban growth and environmental concerns (Smart Government), streamlining traffic (Smart Mobility), and enhancing planning efficiency and resource management (Smart Digital Infrastructure). Successful implementation depends on technology readiness, government support, public-private partnerships, and addressing ethical and privacy concerns.

In the context of AI, Malaysia's Architectural Intelligence (ArcAI) may look to Singapore's established rules and regulations for guidance. This involves implementing ArcAI through three groups: people and communities (Group 1), activity drivers (Group 2), and infrastructure and environment (Group 3), tailored to fit Malaysia's environment, citizens, and culture.

6.0 Conclusions & Recommendations

The research on smart cities and Architectural Intelligence (ArcAI) in Malaysia and Singapore highlights the practical challenges in implementing smart systems, particularly within the Malaysian context. Key obstacles to achieving urban sustainability include managing expansion, providing housing, and balancing environmental concerns amid rapid urbanization and unclear policies. ArcAI emerges as a valuable tool, enhancing resilience, optimizing layouts, and fostering collaboration. Stakeholders perceive ArcAI positively for its role in resource management and decision-making. Critical factors influencing ArcAI adoption include technological maturity and government support. Moving forward, future research should delve deeper into sustainable smartscapes through the lens of ArcAI, with a focus on addressing the pressing issues faced by Malaysian citizens and local governments.

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Paper Contribution to Related Field of Study

The paper offers benefits to stakeholders in the building industry, policymakers, and educational institutions, particularly in the areas of digitalization, ICT, IoT, smart systems, AI, green architecture, and biocentric design, with a focus on enhancing the decision-making process.

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